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14. ABSTRACT

Aerial surveys of marine mammals were performed as part of the Marine Mammal Monitoring on Navy Undersea Acoustic Ranges (3MR) program in three regions: a) Pacific Missile Range Facility (PMRF), Barking Sands, Kauai (BSURE and BARSTUR ranges; Jul 12-Nov 17, 2002); b) Bahamas (Northwest Providence Channel and AUTEC range; Jan 4-12, 2003); and c) main Hawaiian Islands (Feb 21–Apr 5, 2003). The mission was to identify species and record positions and composition of all marine mammal pods sighted. These data were made available to co-investigators (Martin and Moretti) of the 3MR program in order to correlate the visual positions with acoustic localizations using Navy assets.

15. SUBJECT TERMS

Marine mammals, aerial surveys, 3MR Program, monitoring

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FINAL REPORT

GRANT #: N00014-02-1-0841

PRINCIPAL INVESTIGATOR: Joseph R. Mobley, Jr., PhD

INSTITUTION: Marine Mammal Research Consultants, Ltd

AWARD TITLE: MARINE MAMMAL AERIAL SURVEYS IN BAHAMAS AND HAWAII

AWARD PERIOD: 01 JUL 02 to 31 DEC 03

TECHNICAL REPORT:

Background: Due to compliance requirements with the National Environmental Policy Act of 1969, the Marine Mammal Protection Act of 1972, and the Endangered Species Act of 1973, the U.S. Navy has been tasked with developing efficient means of monitoring marine mammals on navy ranges and in the vicinity of navy operations. The Marine Mammal Monitoring on Navy Undersea Acoustic Ranges (3MR) program was devised by ONR to assess the feasibility of using existing assets on U.S. Navy undersea ranges to detect, identify and localize marine mammal species.

Since acoustic detection is an emerging technology, "groundtruthing" of acoustic detections using more widely accepted visual techniques was deemed essential. Aerial surveys offer one such means of visually detecting and identifying marine mammal species, with the additional advantage of efficient and low-cost coverage of broad expanses of ocean. The focus of the present project was on two Navy undersea ranges: the BSURE BARSTUR Range of the Pacific Missile Firing Range (PMRF) off Barking Sands, Kauai and the AUTEC Range off Andros Island, Bahamas (see separate reports by PIs Steve Martin and Dave Moretti for more detailed descriptions of acoustic approaches). Additionally, surveys were conducted throughout the major Hawaiian Islands to complete a ten-year census of marine mammal census in that region.

OBJECTIVE: a) Provide visual groundtruthing to acoustic detections on Naval undersea ranges (as part of Marine Mammal Monitoring on Navy Undersea Acoustic Ranges (3MR) program—with PIs Dave Moretti of NUWC and Steve Martin of SPAWAR); b) Identify incidence and distribution of marine mammal species using aerial surveys in Hawaiian waters (PMRF Range and main Hawaiian Islands) and in the Bahamas (AUTEC Range and Northwest Providence Channel).

APPROACH: Aerial surveys were performed in two regions adjoining Naval undersea acoustic ranges: a) main Hawaiian Islands (PMRF surveys: Jul-Nov 2002) (Figure 1); all main Islands: Feb-Apr 2003, (Figure 2); b) Bahamas (AUTEC Range and Northwest Providence Channel (NPC), Jan 1-12, 2003) (Figures 3-4). All surveys were flown in twin-engine Partenavia Observer aircraft at 244 m altitude and 100 knot speed. Flight personnel consisted of three survey staff (2 observers and 1 data recorder) in addition to the pilot. Trackline construction and survey methods were in accordance with accepted distance sampling procedures (Buckland et al., 2001). Survey protocol was identical to that used in previous aerial surveys of Hawaiian waters (Mobley et al., 2000; Mobley, in press). PMRF surveys were performed in coordination with Steve Martin of SPAWAR Systems Center, San Diego, who was responsible for the acoustic monitoring portion (as part of the 3MR program). Bahamas surveys were performed in coordination with Dave Moretti of NUWC Newport, RI, who was responsible for acoustic monitoring of the AUTEC range. Additionally, two

of the ten Bahamas surveys were performed in collaboration with Diane Claridge, a resident marine mammal biologist on Abaco Island.

ACCOMPLISHMENTS:

PMRF Surveys: We performed 15.1 hrs (1520 nmi) of surveys in the PMRF region and recorded a total of nine sightings. With the exception of one sighting of pilot whales, all sightings were of smaller odontocete species (i.e., dolphins) (Figure 5). The three species positively identified (spotted and spinner dolphins and pilot whales) are ubiquitous throughout the Hawaiian Islands (Mobley et al. 2000). The nine sightings result in a sighting rate of .003 sightings/km of linear effort.

Preliminary analysis of acoustic data from the BARSTUR and BSURE hydrophones (by Steve Martin of SPAWAR Systems Center, San Diego) recorded during periods overlapping with PMRF (reported here) and NPAL aerial surveys (Mobley, in press) showed a correlation between numbers of acoustic and visual detections (Figure 6). The acoustic detections consisted primarily of chorusing humpback whales with some sperm whale clicks. In at least one case, it was possible to correlate acoustic locations of sperm whale clicks with visual sightings of a sperm whale made during the NPAL survey series (Figure 7) (Tiemann, Martin and Mobley, in press).

Bahamas Surveys: Though reports exist describing the incidence of various marine mammal species in waters off the Bahamas (e.g., Balcomb and Claridge, 1997; Claridge, 1998), to our knowledge, this was the first systematic survey of waters in this region using distance sampling methods. During the eight day period, we logged a total of 26 hrs and ca. 4630 km of survey effort. The AUTEC region yielded thirteen sightings, consisting of five identified species (Figure 8). Three of these (pygmy or dwarf sperm whales, *Kogia spp.*, sperm whales, *Physeter macrocephalus*; and roughtoothed dolphins, *Steno bredanensis*) are known to be deep divers, with diets including pelagic squid (Leatherwood et al., 1988). This is consistent with the location of the AUTEC range on the southern end of the Tongue of the Ocean with maximum depth of 2400 m.

The waters of the Northwest Providence Channel produced eight sightings consisting of four species (Figure 9). There were two sightings each of short-finned pilot whales (*Globicephala macrorhynchus*) and bottlenose dolphins (*Tursiops truncatus*) and one sighting each of melon-headed whales (*Peponocephala electra*) and sperm whales (*Physeter macrocephalus*). The majority of these sightings occurred in waters of 500-1000 m in depth.

Figure 10 (prepared by D. Moretti) shows locations of both visual sightings and acoustic detections. Attempts to correlate the two modes of detection were based primarily on spatial and temporal proximity. As shown, one unidentified species of beaked whale was sighted in nearly the same location and within approximately 2.5 min of surface click detections. These acoustic detections likely corresponded to the same animal seen visually.

Hawaiian Island Surveys: A total of 489 sightings were recorded during the 2003 surveys of the main Hawaiian Islands across 9,030 km of linear effort. Of these, 431 (88%) were of humpback whales. Sightings represented ten identified species, nine of which were odontocetes (toothed cetaceans). Species sighted during 2003 were consistent with those described in earlier survey series (Mobley et al., 2000; Mobley et al., 2001).

Humpbacks were generally sighted in shallower waters (Figure 11) with 76% sighted in waters less than 100 fathoms (182 m). Similar to previous surveys (Mobley, Bauer and Herman, 1999) the regions of greatest whale densities were those with the greatest expanses of shallow water. In contrast, the odontocete sightings were seen throughout the range of effort (Figure 12).

When the 2003 data for humpback whales were combined with previous survey data for the Hawaiian Islands (1993, 1995, 1998 and 2000), a ten-year time series of population abundance resulted (1993-2003). As shown in Figure 13, there was a linearly increasing trend up to 2000, then a decline in 2003. This change in trend reinforces the importance of tracking this endangered

population over longer periods in order to clarify whether it is indeed recovering as was previously thought (Mobley et al., 1999; Mobley et al., 2001).

CONCLUSIONS:

a) Low cetacean densities: The biological productivity of tropical island regions, such as Hawaii and the Bahamas, tends to be low relative to that of other areas. As a result, the densities of cetaceans in these regions tend to be correspondingly low. Encounter rates (sightings/km) of cetaceans on the two Navy regions reported here were similarly low: a) PMRF: 9 sightings/2,797 km = .003 sightings/km; b) AUTEC Range: 13 sightings/2,474 km = .005 sightings/km. For the main Hawaiian Islands, sighting rates were much higher when seasonally-resident humpback whales were included: 489 sightings/12,223 km = .040/km. However, when only odontocete species were considered (presumably present year-round), sighting rate reduced to match those of the other two regions (58 sightings/12,223 km = .005 sightings/km). Encounter rates of cetaceans in higher productivity areas such as off the coast of California and in the eastern tropical Pacific (ETP) are generally an order of magnitude higher than this (Barlow, 2003).

b) Visual surveys as groundtruthing approach: In general, despite many hours of survey effort on two instrumented Navy ranges reported here (PMRF and AUTEC) and many acoustic detections, there were very few cases where we were able to correlate the results of these two approaches (Figures 7 and 10). Better success was obtained correlating visual sighting and acoustic detection rates as indicators of relative abundance (Figure 6). One clear advantage of visual survey techniques is their ability to verify the species in question, unlike acoustic detections in most cases (Figure 10). One clear advantage of acoustic detection approaches is their ability to detect a greater number of targets than visual surveys (Figures 6 and 10).

c) Need for long-term monitoring of endangered populations: The results of the 2003 Hawaii surveys showed an abrupt departure from a previous increasing population trend for humpback whales (Figure 13). This finding reinforces the need for long-term monitoring of this endangered species.

SIGNIFICANCE: a) These results further support the feasibility of using existing Navy assets to detect marine mammals; however, more effort is needed in refining the species identification abilities of acoustic techniques; b) These results, in combination with previous marine mammal survey results for the Hawaiian Islands, provided the first long-term time series of humpback whale abundance in Hawaiian waters (1993-2003); c) The survey results for the Bahamas represent the first systematic survey of marine mammals in those waters using distance sampling methods.

PATENT INFORMATION: N/A

AWARD INFORMATION: N/A

PUBLICATIONS AND ABSTRACTS (for total period of grant):

Journal Article:

Tiemann, C., Martin S.W. and Mobley, Jr., J.R. (in press). Aerial and acoustic marine mammal detection and localization on Navy ranges. *IEEE Journal of Oceanographic Engineering*

Conference Presentations:

Mobley, Jr. Conducting aerial surveys of marine mammals. Navy Range Acoustic Monitoring Program (RAMP) workshop, San Diego, CA, June 8-9, 2004.

Mobley, Jr., Deakos, M. and Newcomer, M. Mobley, Jr., J.R., Deakos, M. and Newcomer, M. Results of aerial surveys off the Bahamas. Presented at the 15th Biennial Conference on the Biology of Marine Mammals Greensboro, NC, 14-19 December 2003.

Martin, S.W. and Mobley, Jr., J.R. Aerial and acoustic marine mammal monitoring on a Navy instrumented test range. Presented at the 15th Biennial Conference on the Biology of Marine Mammals Greensboro, NC, 14-19 December 2003.

Moretti, D.J., Jarvis, S., DiMarzio, N., Morrissey, R. and Mobley, J. The efficacy of passive acoustics for the detection and localization of marine mammals as compared to a visual aerial survey, Environmental Consequences of Underwater Sound (ECOUS) Symposium, San Antonio, Texas, 12-16 May 2003. Abstracts.

Martin, S.W. and Mobley, Jr., J. R. Passive acoustic marine mammal monitoring at a Navy instrumented test range. Environmental Consequences of Underwater Sound (ECOUS) Symposium, San Antonio, Texas, 12-16 May 2003. Abstracts.

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Mobley, Jr. (in press). Assessing responses of humpback whales to NPAL transmissions: Results of 2001-2003 aerial surveys north of Kauai. *Journal of the Acoustical Society of America*.

Mobley, Jr., J. R., Bauer, G. A. and Herman, L. M. (1999). Changes over a ten-year period in the distribution and relative abundance of humpback whales (*Megaptera novaengliae*) wintering in Hawaiian waters. *Aquatic Mammals, 25(2):63-72.*

Mobley, Jr., J.R., Spitz, S.S., Forney, K.A., Grotefendt, R.A. and Forestell, P.H. (2000). Distribution and abundance of odontocete species in Hawaiian waters: Preliminary results of 1993-98 aerial surveys. Report to Southwest Fisheries Science Center, Administrative Report LJ-00-14C. 26 pp.

Mobley, Jr., J.R., Spitz, S.S., Grotefendt, R.A., Forestell, P.H., Frankel, A. and Bauer, G.B. (2001). Abundance of humpback whales in Hawaiian waters: Results of 1993-2000 aerial surveys. Report to the Hawaiian Islands Humpback Whale National Marine Sanctuary, 16 pp.

Tiemann, C., Martin S.W. and Mobley, Jr., J.R. (in press). Aerial and acoustic marine mammal detection and localization on Navy ranges. *IEEE Journal of Oceanographic Engineering*

FIGURES:

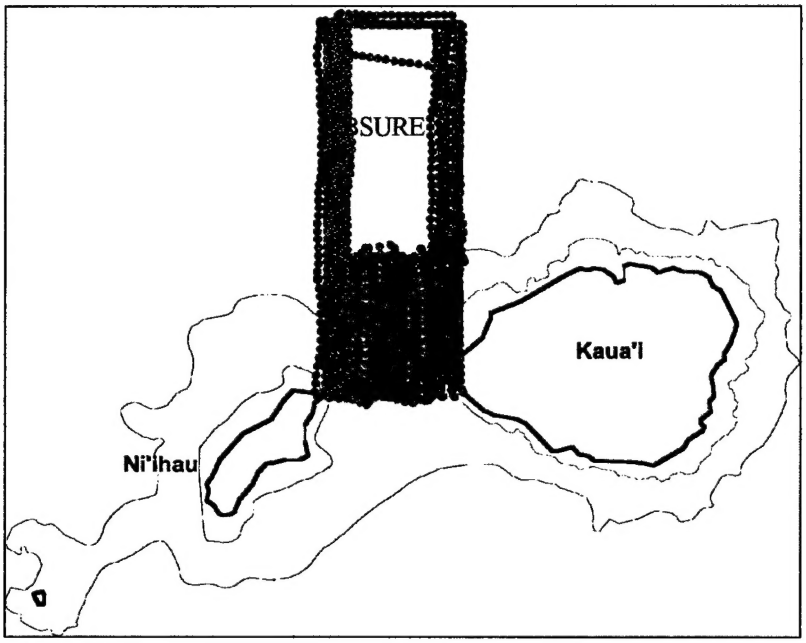

Figure 1. PMRF Survey Effort. Ten surveys were flown over the BARSTUR and BSURE hydrophone ranges during the period Jul 12 to Nov 17, 2002. Inner and outer bathymetry lines indicate 100 and 1000 fathom contours, respectively.

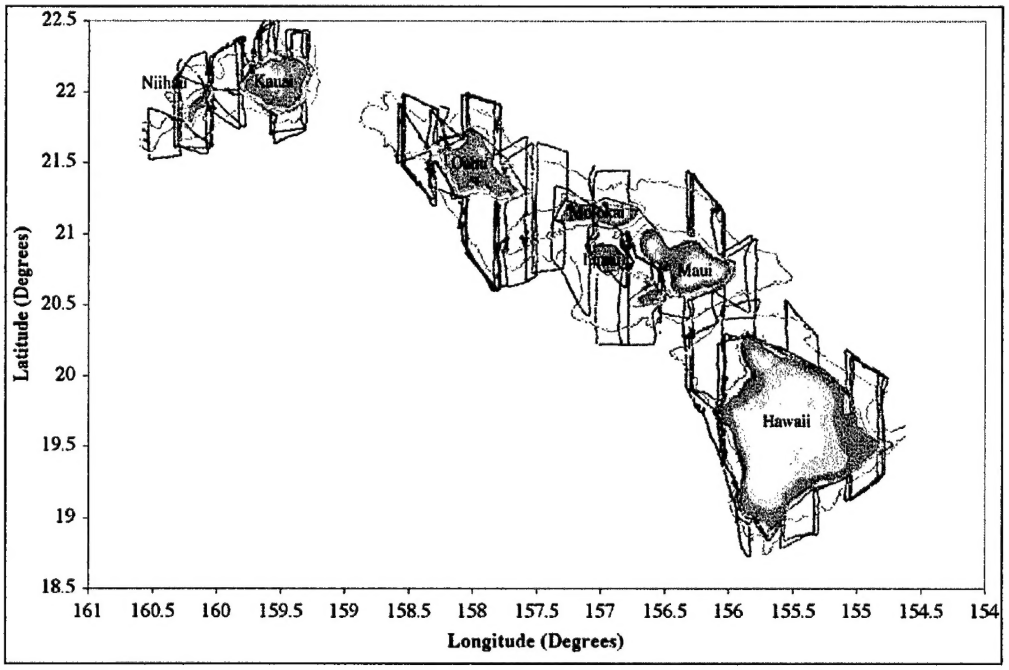

Figure 2. Hawaii Survey Effort. Red lines indicate survey effort (total = 9,030 km). Inner and outer (grey) bathymetry lines indicate 100 and 1000 fathom contours, respectively.

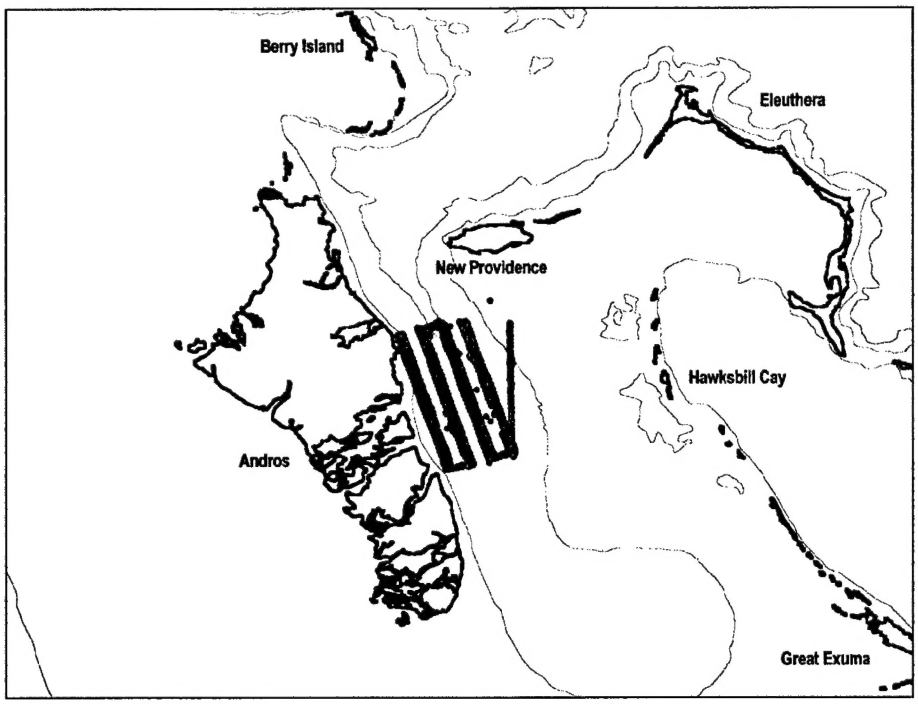

Figure 3. AUTEC survey effort. Tracklines were spaced 4 nmi apart and 30 nmi long. Inner and outer bathymetry contours correspond to the 100 and 1000 fathom lines, respectively. The Tongue of the Ocean is the deep water channel running through the AUTEC Range.

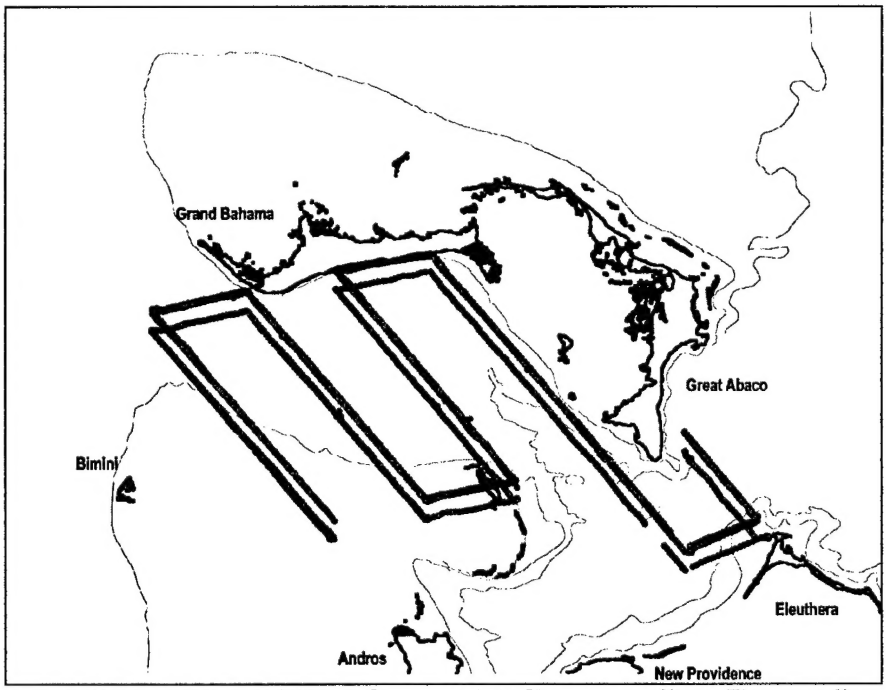

Figure 4. Northwest Providence Channel (NPC) survey effort. Transect lines were spaced 15 nautical miles (nmi) apart for a total linear effort of ca. 350 nmi. Bathymetry contour is 100 fathom limit.

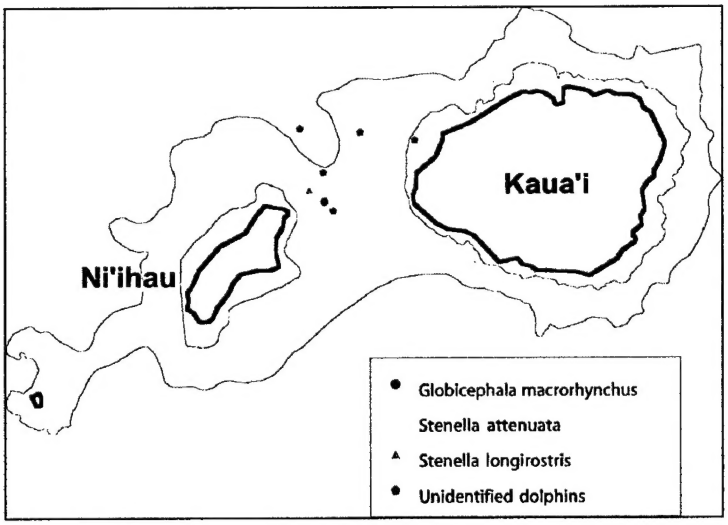

Figure 5. PMRF Sightings. A total of nine sightings were recorded during the 10 surveys, involving three confirmed species. Inner contour is 100 fathoms; outer is 1000 fathoms.

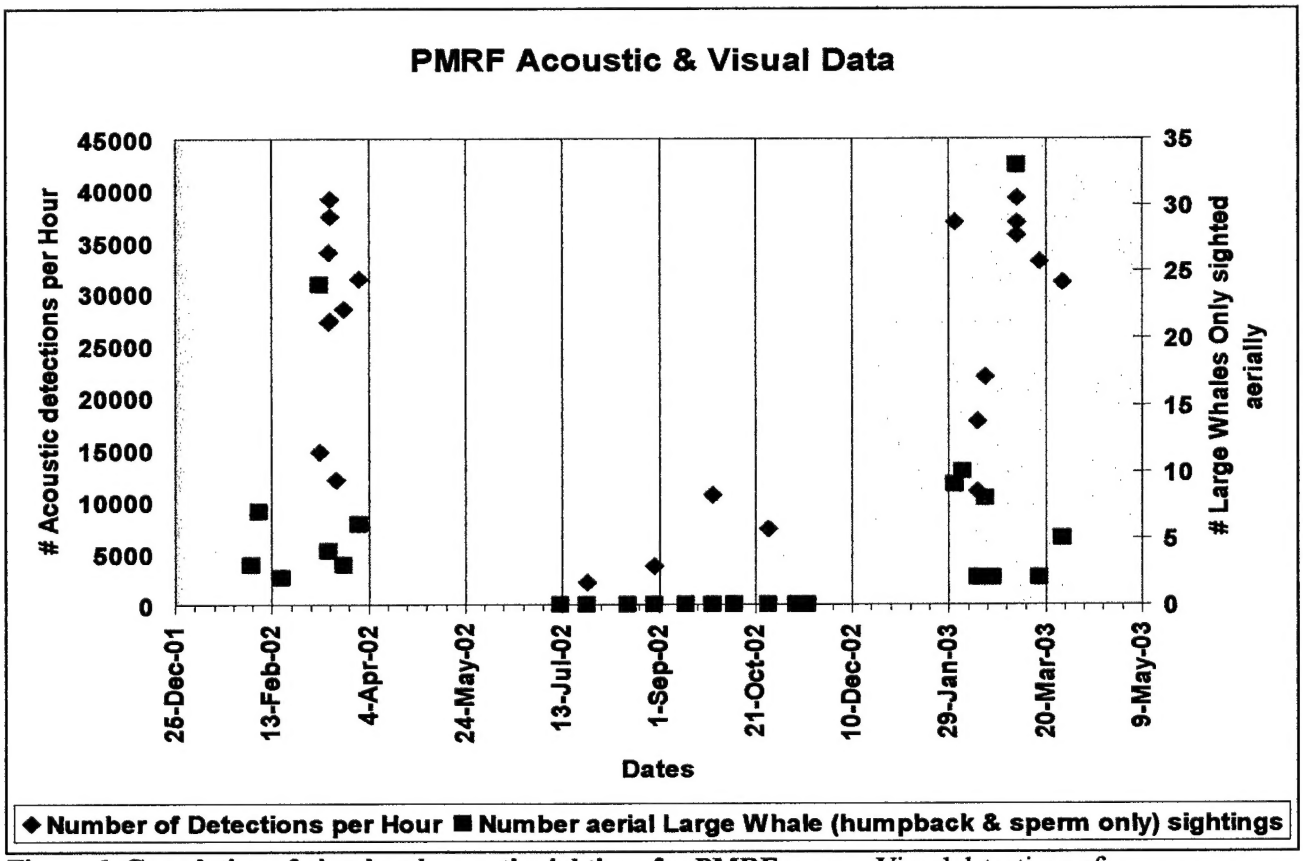

Figure 6. Correlation of visual and acoustic sightings for PMRF range. Visual detections of sperm and humpback whales (red squares) from the PMRF surveys (Jul – Nov 02) and NPAL surveys (Feb – Mar 02 and Feb – Mar 03) tended to correlate with acoustic detections (blue diamonds) from the BARSTUR and BSURE range hydrophones (Figure from Tiemann, Martin and Mobley, in press).

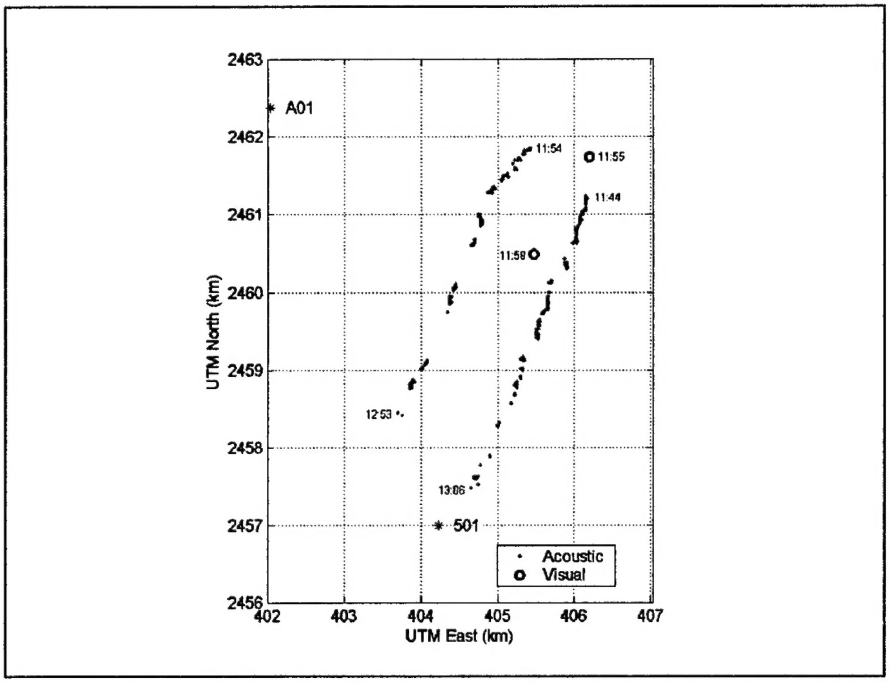

Figure 7. Plot of two sperm whales tracked acoustically using BSURE phones on PMRF Range (red dots). Blue circles indicate locations of visual sightings of sperm whales during NPAL aerial surveys. These were judged to likely be at least in the same group as the vocalizing whales, if not the same individuals (from Tiemann, Martin and Mobley, in press).

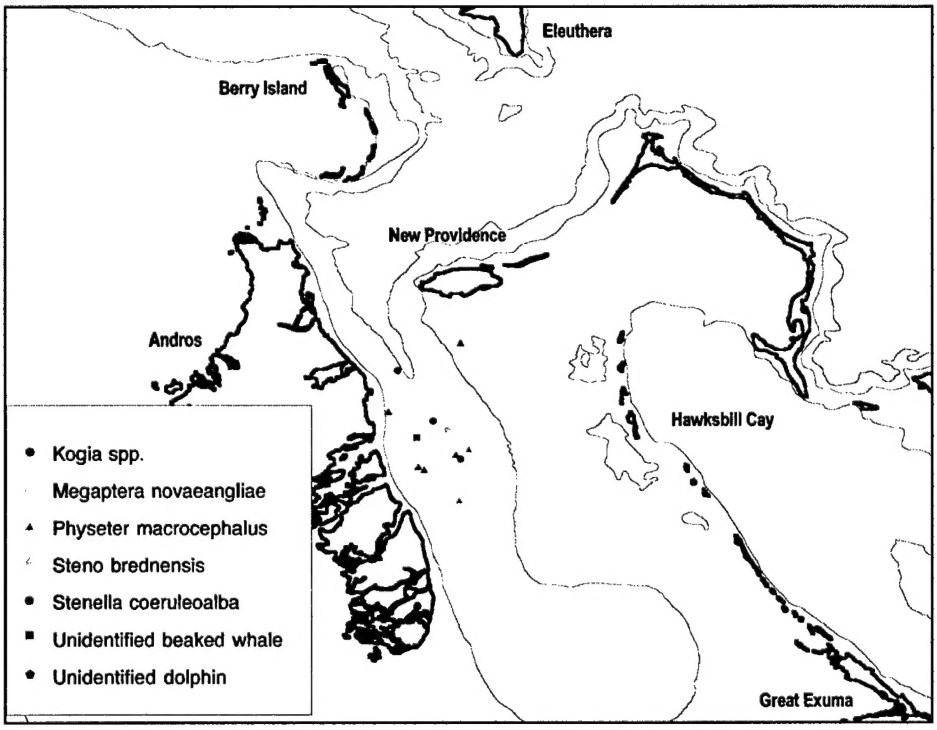

Figure 8. Marine mammal sightings on AUTEC range—Thirteen sightings were recorded during 13.36 hrs of surveys involving five positively identified species. Bathymetry contours correspond to 100 and 1000 fathom limits.

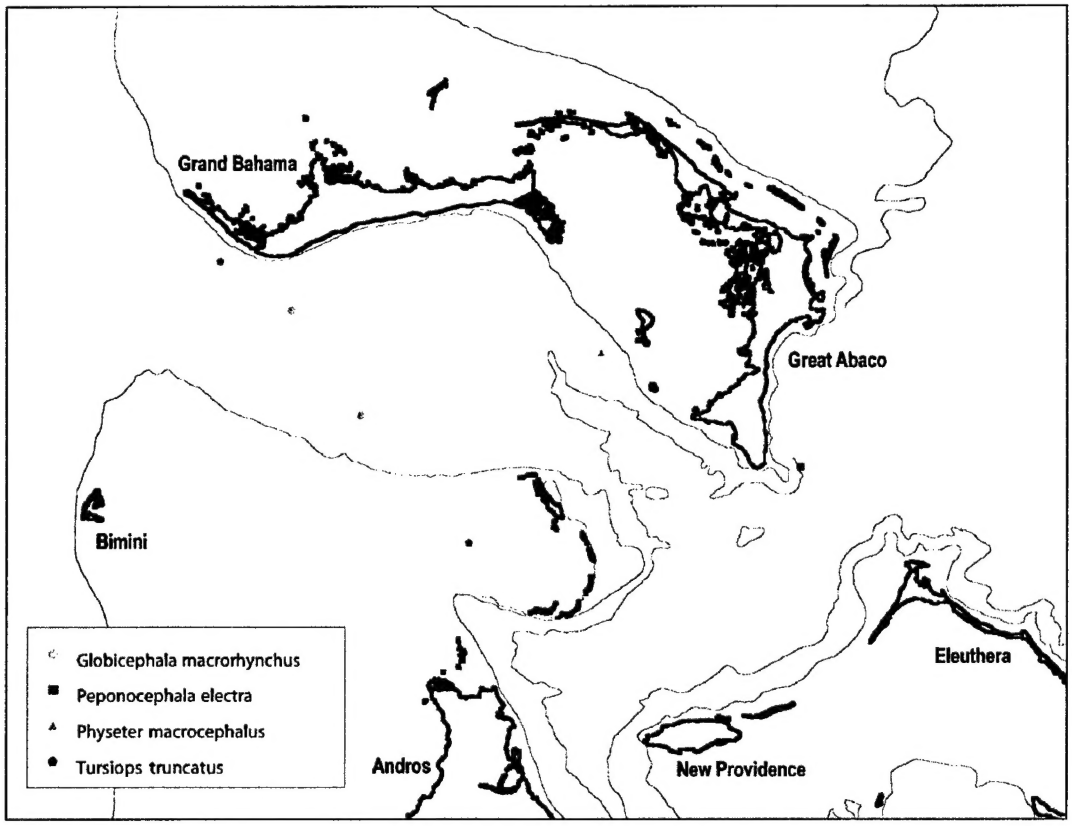

Figure 9. Northwest Providence Channel sightings. Eight sightings were recorded during 12.75 hrs of effort involving four identified species. Bathymetry contour corresponds to 100 fathom limit.

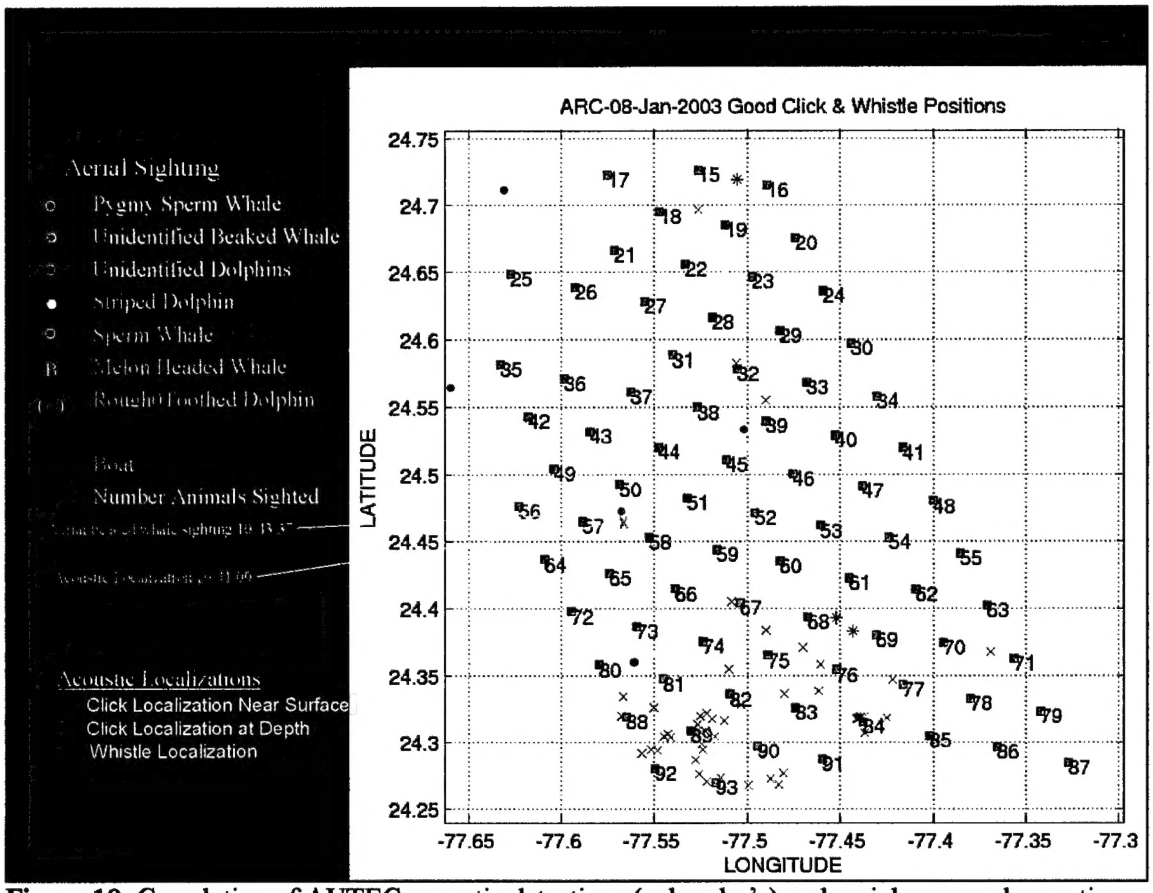

Figure 10. Correlation of AUTEC acoustic detections (colored x's) and aerial survey observations (colored dots) (slide prepared by D. Moretti). Correlation of acoustic and visual locations was possible in the case of an unidentified beaked whale sighted visually at 10:43:37 hrs with nearby acoustic click detection at 10:41:00 hrs.

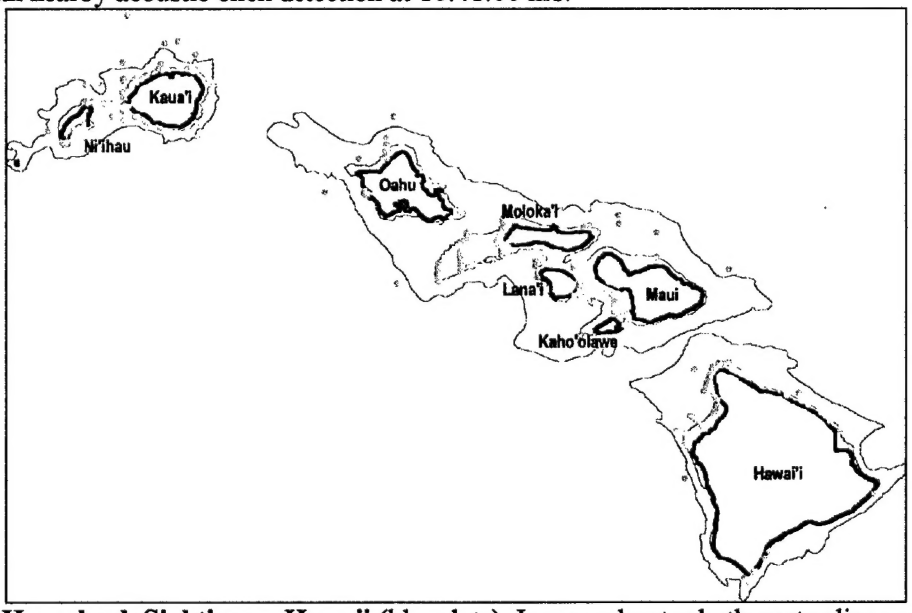

Figure 11 Humpback Sightings—Hawaii (blue dots). Inner and outer bathymetry lines refer to 100 and 1000 fathom contours, respectively. The majority of humpbacks were seen inside the 100-fathom limit.

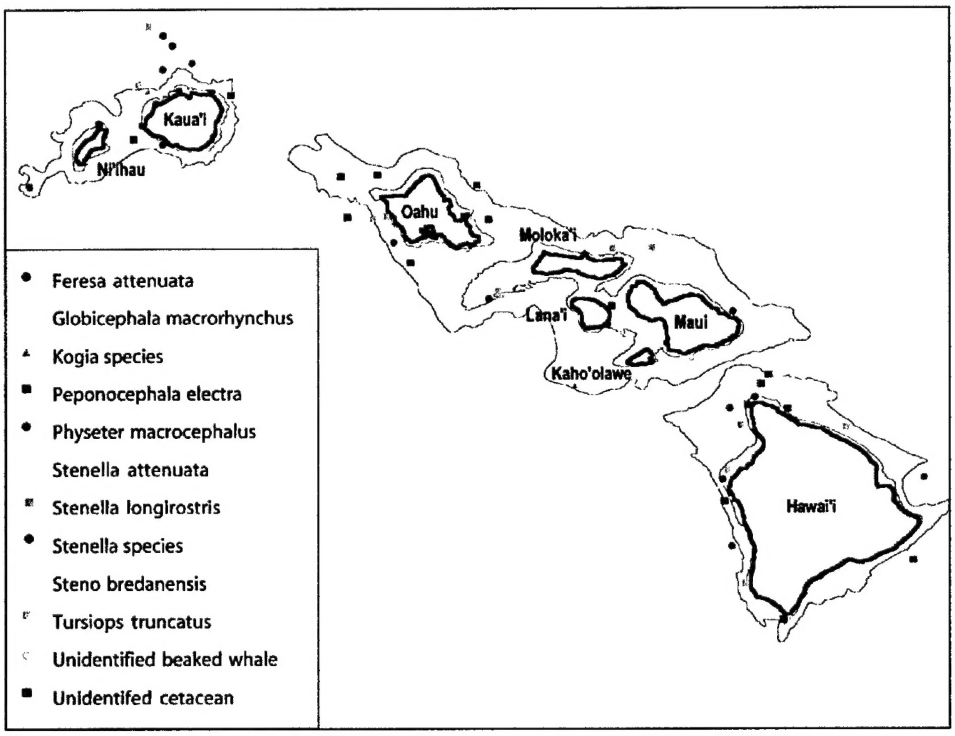

Figure 12. Odontocete Sightings—Hawaii. A total of 56 odontocete sightings were made during the 2003 surveys of waters adjoining the major Hawaiian Islands, representing nine identified species. Inner and outer bathymetry lines represent 100 and 1000 fathom contours respectively.

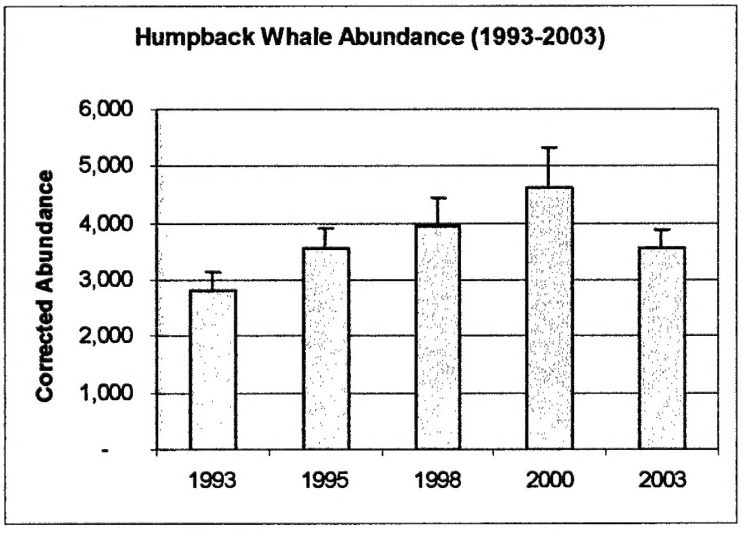

Figure 13. Humpback whale abundance estimates based on corrected densities (corrected using respiration data) for 1993-2003 survey results (vertical bars show standard errors).